# SYLLABUS OF MASTER OF CHEMICAL ENGINEERING

## First semester

### Category -Departmental / Specialization Basket

### PAPER-I

#### PG / ChE / T / 111A -Advanced Chemical Engineering Thermodynamics

Review of first and second laws of thermodynamics, General methods of deriving thermodynamic formulae; Partial molal quantities-Gibbs-Duhem equation; Equilibrium and free energy, fugacity and activity; Chemical reaction equilibrium constants; fugacity in mixture; effect of pressure, volume, temperature on thermodynamic properties such as enthalpy, entropy, internal energy etc. chemical potential in mixtures; vapour-liquid equilibrium,Correlation of data from Van taar and other equations. Elements of irreversible and statistical thermodynamics.

#### PG / ChE / T / 111B -Advanced Chemical Engineering Kinetics and Reactor Design

Kinetics of homogenous complex reaction; Kinetics of Fluid-solid and fluid-fluid catalytic and non-catalytic reactions; Heterogenous catalysis, : Reaction and Diffusion with porous catalyst, solid catalysed reactions, Mass and heat transfer in catalytic beds; Non-ideal reactor performance. Design of stirred reactors; Bubble column reactors, Slurry reactors, adiabatic and programmed reactors.

Modelling of Multi-phase Reactors; Dynamic behaviour of chemical reactors, Reactor optimization and scale up.

Stability analysis of Reactors, Parametric sensivity in Autothermal Reactors, multiplicity and Hysteresis in CSTR and PFR, Bifurcation Theorem.

#### PG / ChE / T / 111C -Process Dynamics and Control

Process dynamic analysis by State varible technique. Definition of state, state matrix, solution of differential equations, Open loop and close loop system representation, Lumped parameter, Lumped parameter with stages, distributed parameter systems. Controllability, observability. Solution through simulator like MATLAB.

Process identification methods-time domain and frequency domain methods, OFF-line and OB-line methods.

Design techniques-Direct substitution method (Dahlin's Algorithm), Internal Model reference method.

Analysis and design of advance control strategies-Feed forward, Cascade, Smith's Predictor Algorithm, Adaptive control strategies-self Tuning regulators, Model reference Adaptive control strategies – self tuning regulators, Model reference adaptive algorithm.

Optimal control-criteria of optimality.

Introduction to Nonlinear systems – Describing function technique, phase plane analysis, Liapunov's stability criterion-exothermic reactor system.

Plant wide process control-Analysis and synthesis through example case studies.

Discrete systems, sampled data systems, Z-transform – Pulse transfer function, modified sort form, Controller synthesis, stability analysis. Computer based control system.

**PAPER-II**

**PG / ChE / T/ 112A -Advanced Heat Transfer**

General equation of heat conduction. Application of general heat conduction equation under steady state heat conduction with internal heat generation in large slab, cylinder, hollow cylinder etc. Transient heat conduction numerical and analytical methods for the solution of transient heat conduction problems. Series-parallel resistances and contact resistances in heat transfer concept of conduction shape factor, critical radices and optimum thickness of insulation.

Free convective heat transfer under different situations and application of dimensional analysis to estimate the convective heat transfer coefficients. Forced convective heat transfer in laminar-transition and Turbulent zone.

Heat transfer factor Reynolds No. plot. Analogy equation for Heat Momentum Transfer. Convective heat transfer in molten method. Boiling heat transfer with particular reference to Nucleate and film boiling and estimation of boiling heat transfer coefficient. Heat transfer from condensing vapors. Nusselt equation for film type condensation of vapors over vertical surfaces and inclined tubes.

Selection and design of condensers, single pass and multipass heat exchangers. Radiation heat transfer. Estimation of view factors and emmisivity factors for different situation. Radiation shield and radiation error in pyrometry.

Combined conduction, convention and radiation heat transfer. Convection and Radiation heat transfer furnaces.

**PG / ChE / T/ 112B -Advanced Mass Transfer**

Simulation of cascade processes by
Stage to stage calculations
Lewis-matheson method
Thiele-Geddes method
Matrix methods
BP method
Napthali Sandholm method
Incorporation of tray efficiencies in matrix method
Supercritical extraction
Adsorption
Fundamentals of adsorption including phase diagrams, estimation of phase equilibria by Langmuir, Freundlich, Ideal adsorped solution theory etc.
Fixed bed adsorbers
basic concepts, Dynamic modeling of fixed bed adsorbers
Temperature swing adsorption
pressure swing adsorption
PSA cycles – basic principles
Dynamic modeling of PSA system
Simulated continuous countercurrent systems
Simulation by Mc Cabe Thiele and Kremser method, SMB
Chromatography
Hybrid processes
reaction distillation, membrane distillation etc.
Estimation of multi-component mass transfer rates
Maxwell Stefan relations

Estimation of diffusion constants, effective diffusivity methods
Mass transfer coefficients
Bootstrap problem
Process Intensification

**PG / ChE / T/ 112C -Advanced Fluid Dynamics**

Vector and Tensor Methods
The Physical Properties of Fluids
Kinematics of the Flow Field: Specification of the flow field, conservation of mass, Analysis of relative motion near a point,
Expression for the velocity distribution with specified rate of expansion and vorticity, Sources and Sinks, The voriticity distribution, velocity distribution with zero rate of expansion and zero vorticity.
Equations Governing Motion of a Fluid: Material Integrals in a moving fluid, The Equation of motion, The expression for the stress tensor, Constitutive relationships, Non-Newtonian Fluids, Navier Stokes Equation, Bernoulli's theorem for steady flow of a frictionless non-conducting fluid, Boundary conditions for real fluid, Fluid mechanics at the interface.
Flow of a Uniform Incompressible Viscous Fluid: Steady unidirectional flow, Unsteady unidirectional flow, Flow with circular streamlines, Flow fields in which inertial forces are negligible, Flow due to moving body at small Reynolds number, The viscosity of dilute suspension of small particles.
Flow at Large Reynolds Number: Vorticity dynamics, Kelvin's circulation theorem, vorticity laws for an inviscid fluid, Steady two dimensional flow in a converging or diverging channel.
Boundary Layers: Integral methods, Scaling, Blasius flow, Falkner-Skan flow, Separation of boundary layer
Transition and Turbulence: Turbulent flow fluctuating velocity, turbulent stress, mean fluctuating velocity, mixing length, Prandtl's and Karman's theories, theory of momentum transfer
Two phase flow conditions at gas liquid interface: equation for mean velocity of two phase streams, flow in their film, wave formation on surface, frictional losses.
Hydrodynamic instabilities in open and closed flows: Linear instability concept, Nonlinear instability concept

**Text Book:**

An Introduction to Fluid Dynamics, G.K. Batchelor, Cambridge University Press, Indian Edition 1993, Reprint 1997.

**References:**

Physical Fluid Dynamics, D. J. Tritton, Oxford Univ. Press., 1988.
Analysis of Transport phenomena, M. Deen, Oxford Universityu Press, 1998
Ideal and Incompressible fluid dynamics, M. E,. O'Neill, F. Chorlton, John Wiley & Sons.
Hydrodynamics and Nonlinear Instabilities, Claude Godriche, Paul Manneville, Cambridge University Press, 1998.

**PAPER-III**

**PG / ChE / T/ 113A -Advanced Transport Phenomena**

Unsteady heat, mass and momentum transfer in more than one dimensions in spherical and cylindrical co-ordinates.
Mass transfer with chemical reactions.
Differential and integral analysis of momentum, thermal and concentration boundary layers and their approximate and exact solutions. Turbulent boundary layers.
Problems involving non Newtonian fluids.
Analysis of compressible flow.
Two-phase flow
Simultaneous heat, mass and momentum transfer.

**PG / ChE / T/ 113B -Numerical Methods for Chemical Engineering**

Numerical solution of nonlinear algebric equations : types of roots and their approximation; Regula Falsi, Newton-Raphson and Greffe's methods; Newton's methods for real and complex roots and simultaneous nonlinear algebric equations.

Numerical solution of simultaneous linear algebraic equations : consistency of equations and existence of solution; Gauss elimination method; Gauss-Jordan reduction method with matrix inversion; Gauss-Seidel substitution method.

Homogeneous algebraic equations and characteristic-value: Fadder-Laverrier method, elementary similarity transformation, the QR algorithm of successive factorization.

Finite difference methods : symbolic operators; various differences; difference equations and their solutions; interpolating polynomials; interpolation; orthogonal polynomials.
Numerical solution of ordinary differential equations : classification, transformation to canonical forms; linear ordinary differential equations, integration formulas. Nonlinear ordinary differential equations-initial value problems : The Euler's methods, the Runge- Kutta methods; simultaneous ordinary differential equations. Nonlinear ordinary differential equations-boundary value problems : The Newton's method, finite difference method, collocation methods. Error propagation, stability and convergence. Stiff differential equations.
Numerical solution of partial differential equations : classification, initial and boundary conditions; finite difference method of solution for elliptic, parabolic and hyperbolic partial differential equations. Irregular boundary and polar coordinate system. Nonlinear partial differential equations; finite element method.
Linear and nonlinear regression analysis : process analysis, mathematical analysis and regression analysis; statistical terminology; derivation of normal equations and properties of estimated vector of parameters for linear regression. The Gauss-Newton method, steepest descent method and the Marquardt method for nonlinear analysis; analysis of variance and other statistical tests of the regression results.

**Category:- Inter-Disciplinary Basket**

**PAPER-IV**

Any one subject from the inter-disciplinary basket of ME, IE, CE, EE, ETCE, MetE Departments.

**PAPER-V**

**PG / ChE / T/ 115A -Environmental Pollution Control**

Definition, Glossaries on different Environmental Descriptors, Natural and Anthropogenic pollution, Sustainable development, Procedural interaction with legal authorities, Environmental protection Acts, Rules. Statutory standards, conceptual aspects of EIA, ES, EMP, Hazardous substances & Risk analysis.

Water and Atmospheric pollution – types, causes sources, primary and secondary pollutants, effects, dispersion of Air pollutants, rudiments of control measures, standards solid waste-classification, collection and disposal management, Noise pollution – causes and effects, control measures, global atmosphere change.

Concept of Ecology, Productivity Cycle, Food chain, limnology, Nutrient cycle, Eutrophication, Ecopond system, a few case studies related to environmental issues.

**PG / ChE / T/ 115B -Interfacial Science and Engineering**

Physics of surfaces

Surface and Interface- molecular origin, the work of cohesion and adhesion

Interaction forces and potential, chemical and physical interaction, classification of physical forces. Van der Waals force, interaction between surface and particles – Lifshitz theory, hydrodynamic flow effects in interfacial interactions

Electrostatics forces and electric double layer, DLVO theory, Boltzmann distribution, Debye length, specific ion adsorption, ion adsorption, Stern layer, Electrphoresis

Theory of capillarity – Young Laplace equation, capillary flow and spreading process, wetting and spreading, contact angle and its measurement technique, contact angle hysterisis, Thermodymanics of wetting, Young's equation, spreading coefficient

Equilibrium dynamics and stability of free liquid surfaces

Chemical equilibrium across a curved interface, generalized Kelvin equation, Oswald ripening, Capillary condensation, Theory of heterogeneous nucleation

Effects of solutes on surface tension, Adsorption, Gibbs surface excess, Gibbs adsorption equation, Adsorption isotherms, surfactant adsorption

Surfactants, self assembly thermodynamics, bilayers, vesicles, phase diagram

Stability of colloids – emulsions, microemulsions, foams, aerosols, polymers at interface

Application involving various colloidal system.

**Alternately,** any one subject from the inter-disciplinary basket of ME, IE, CE, EE, ETCE, MetE Departments.

**PAPER-VI**

Any one subject from the inter-disciplinary basket of ME, IE, CE, EE, ETCE, MetE Departments.

**Category:- Sessional Courses**

**Sessional I**

**PG / ChE / S / 111-Laboratory**

**Sessional II**

**PG / ChE / S / 112-Seminar**

## Second Semester

**Category:- Departmental / Specialization Basket**

**PAPER-VII**

**PG / ChE / T/ 127A -Modern Energy Engineering and Energy Management**

Concept of "waste to energy"; Thermochemical and biochemical conversion of Biomass; Kinetics of incineration, Pyrolysis and Gasification (low and medium Joule) of Biomass and polymeric Wastes; Design of incinerator, Green House effect of Incineration; Design of Updraft, downdraft and fluidized bed Gasifiers for Biomass; Design of low temperature pyrolyser and Fast/Flash Pyrolyser; Kinetics of Biogas generation from wastes; Design of Bio-digesters for the generation of Biogas; Gas Turbines and Dual-fuel IC engines for power generation from low and medium Joule gases; use of Natural gas for the substitution of liquid fuels; Dehydration and Desulfurization processes of natural gas; gathering and transport of natural gas and Biogas; concept and operation of fuel cell;

Design and scale-up of solar appliances including photoyoltaics; co-generation: Theory and practice; energy system control and management; codes, standard and legislation for energy usage; Energy auditing in process industries; waste heat recovery.

**PG / ChE / T/ 127B -Pollution Control and Safety in Process Industries**

Introduction to Ecology and Ecosystems, Environment quality and resource management.

Impact of technology, population growth and urbanization on ecosystem.

Water Resources and water quality for domestic, Industrial uses. Water treatment methods.

Physical and chemical characteristics of waste water, measurement of organic content-BOD. COD, TOC etc. Biological Protista, characteristics of waste water, Microorganisms, Procasyotic and Encayotic cells.

Waste water treatment and Physical Unit OpcrationsScreening Floculation, Sedimentation Flotation, Filtration, Disposal of sludge, Chemical treatmept, Chlorination, Biological treatment Cell physiology, aerobic and anaerobic cycles, growth kinetics, activated biological sludge process, trioxle filter, stabilization ponds and other processes and design considerations.

Advanced waste water treatment, processes tor industrial effiuents.

Treatment and disposal of sludge and solid wastes. Sanitary landftll and composing. Incinerators design, Pyrolysis and other energy recovery processes. Treatment of agricultural wastes and manure. Biogas.

Air environment and its management. Nature of air pollutants and their effects. Sampling and array methods. Particulars and their removal methods-mechanical removal devices and electrostatic precipitators-design considerations. Reduction of automobile engine exhaust emissions.

Treatment of flue gases. Process design considerations for reducing emission.

Case studies particularly from chemical process industries. Safety analysis.

**PG / ChE / T/ 127C -Petroleum Refinery Engineering and Petrochemicals**

Origin, formation and composition of petroleum. Evaluation of crude oil. Properties and testing of petroleum products. Pretreatment of crude oil and crude oil distillation. Fuel quality management of transportation fuels. Secondary conversion processes in petroleum refineries – cracking, alkylation, isomerisation, polymerization, hydrocracking, coking, visbreaking etc. Treatment and purification of petroleum products. Corrosion in refineries. Design of pipe-still heaters and multicomponent distillation systems.

Scope of petrochemical industry, Feedstock identification – conventional and alternate. Synthesis gas and chemicals from petroleum hydrocarbons. Polymers of olefins. Synthetic fibres. Synthetic rubber. Plastics, synthetic detergents, and petroleum coke & carbon black.

**PAPER-VIII**

**PG / ChE / T/ 128A -Computational Fluid Dynamics**

OVERVIEW OF CFD
Role of CFD
Problem solving in CFD
Components of CFD Softwares
GOVERNING EQUATIONS
Complete Navier-Stokes Equations
Complete Energy Equations
Complete Mass conservation Equations
Parabolized Navier-Stokes Equations
Euler Equations
Turbulence Modeling
COSERVATION LAWS AND CONSERVATION FORM OF EQUATIONS
Conservative and non conservative forms
Source terms and boundary conditions
APPROXIMATION OF GOVERNING EQUATIONS
Finite difference methods
Finite Volume methods
Finite Element methods
GRID GENERATION
Structured Grid generation
Unstructured Grid generation
Adaptive Grid generation
SOLUTION ALGORITHMS AND TECHNIQUES
LU decomposition
Approximate factorization
Relaxation algorithms
Hybrid Schemes
CFD METHODS FOR THE EULAR EQUATION
Linearization and Jacobian Matrix
Eigenvalues and Eigenvectors
Flux splitting methods
CFD METHODS FOR NAVIER-STOKES EQUATIONS
Beam-Warming algorithm

MacCormack's scheme
Upwind Techniques
PRESENTATION OF CFD RESULTS
INTRODUCTION PARALLEL COMPUTING
BOOKS: 1. Computational Fluid Dynamics – J. D. Anderson, McGraw-Hill
2. Computational Fluid Mechanics and Heat Transfer – J.C. Tannehill, D.A.Anderson, R.H. Pletcher, Taylor and Francis
3. Computational Fluid Dynamics – T. J. Chung ,Cambridge University Press

**PG / ChE / T/ 128B -Optimization Methods**

Introduction to optimisation.

Classical optimisation techniques.

Linear programming.

Nonlinear programming: One dimensional, Cons
trained and unconstrained optimisation technique.
Geometric. Programming.

Dynamic Programming.

Integer Programming: Linear and nonlinear.

Stochastic Programming.

Calculus of variation, PERT & CPM, game theory, Quadratic Programming.

**PG / ChE / T/ 128C -Modeling and Simulation of Chemical Processes**

Use and scope of mathematical models in chemical Engg. practise. Development of models involving mass, momentum and energy transfer processes with or without chemical reactions.
Mathemetical tools and simulation techniques in chemical engineering process plants and their design.
Modelling and simulation of flow tanks, distillation columns with or without hold-up, reactors and other chemical Engineering equipment.

**PG / ChE / T/ 128D -Applied Statistics for Chemical Engineering**

Concept of Histogram, Frequency polygon and other pictorial representations;
Central Tendency;
Dispersion measure;
Testing of hypothesis: Z, t, F, Chi-square distributions;
Annova Analysis of variant;
Contingency Test & goodness of fit;
Non parametric method ( H, U );
Nonlinear least square technique – parametric sensitivity;
Problems related to Chemical Processes.

**PAPER-IX**

**PG / ChE / T/ 129A -Biochemical Engineering**

Introduction to the Kinetics of Bioprocesses; Enzyme Kenetics; Cell
Growth Kinetics; Kinetics of metabolic Product Synthesis by cells; Introduction of Segregated and Non-segregated Models; Kinetics of Immobilized Enzymes and cells; scale-up and control of Bioreactors; Parametric sensitivity and Multiplicity in

Biosystems; Global and Local stability analyses of Bioreactors; Kinetics and Reaction engineering of genetically modified cell cultures, Recombinant DNA technology, Downstream processing in Bioprocesses; Industrial Application of Bioprocesses.

**PG / ChE / T/ 129B -Membrane Science and Engineering**

Overview of the membrane separation processes: Historical development, Current status, Different membrane separation processes
Reverse Osmosis (RO)
Process decription and terminology
Driving force
Theory: Different models: Solution-Diffusion model, Solution-Diffusion Imperfection model, Preferential Sorption Capillary Flow model, Surface Force Pore Flow model, etc.
Concentration polarization
Application
Ultrafiltration (UF)
Inroduction, Definition
Theory: Different macroscopic and microscopic model
Concentration polarization
Membranes & module design
Application
Microfiltration (MF)
Overview/ Defination
Theory: Dead-end Microfiltration, Cross-flow Microfiltration
Application
Emulsion Liquid membrane (ELM)
Concepts/ Defination
Theory
Design Consideration
Application
Gas separation: Effusion and Permeation
Pervaporation
Dialysis/ Electro-dialysis: Theory and Application
New membrane separation processes

**PG / ChE / T/ 129C -High Polymer Engineering**

Fundamental concepts of High polymers, classification of High polymers, polymerization methods, kinetics of course
Addition, Condensation and Ring opening polymerization, Reactor Design, Determination of Molecular weight and Molecular weight distribution, Rubbery State and compounding of natural and synthetic rubber, classification of polymer forming operations, Principles of Injection Moulding, Extrusion, Calendering, Blow moulding, Lamination.

**Category:- Inter-Disciplinary Basket**

**PAPER-X**

**PG / ChE / T/ 1210A -Bioenergetics and Bioprocess Engineering**

Biochemical reaction engineering, Kinetics of homogeneous reactions, reaction mechanism, Temperature dependency from Arrhenius law, Interpretation of batch kinetic data, Kinetics of enzyme catalyzed reaction in free and immobilized states, Michaelis –Menten kinetics of substrate utilization, product formation and biomass production, Monod growth model and its various modifications with special reference to inhibition by substrate, product and toxic materials, structured and unstructured kinetic rate model, thermal death kineticsof cells and spores, Different types of bioreactors for suspension and immobilized cultures, solid state fermentation, protein-protein and protein-DNA interaction, basics of genetic engineering, Chemical mechanisms of biological energy conversion in mitochondria and chloroplasts, application of bioprocesses in energy generation( generation of bioethanol, biodiesel, biogas etc., microbial fuel cell ), introduction to algal biotechnology, factors affecting algal growth, photobioreactors, photosynthesis in high density medium.

**Alternately,** any one subject from the inter-disciplinary basket of ME, IE, CE, EE, ETCE, MetE Departments.

**Category:- Sessional Courses**

**Sessional I**

**PG / ChE / S / 121-Term Paper Leading to Thesis**

**Sessional II**

**PG / ChE / S / 122-Seminar**

## THIRD and FOURTH SEMESTER

**Category:- Sessional Courses**

**Sessional I**

**PG / ChE / TH / 21-Thesis Work**

**Sessional II**

**PG / ChE / VV/ 22-Viva-voce**